NAIC-ID(RS)T-0376-95

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by

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HUMAN TRANSLATION

NAIC-ID(RS)T-0376-95 21 November 1995

MICROFICHE NR: 95C000713

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English pages: 11

Source: Hangkong Xuebao, Vol. 15, Nr. 12, December 1994; pp. 1445-1449

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TATV/Beverly G. Brown
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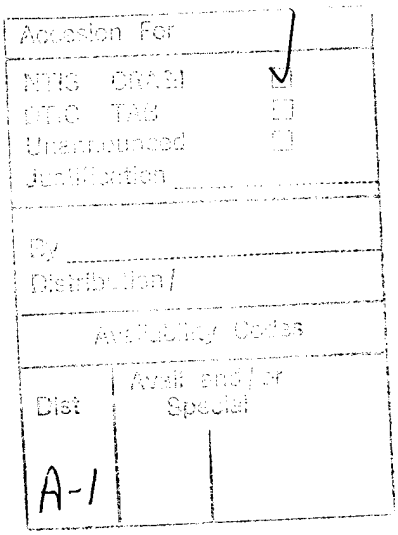
ABSTRACT This article researchs XD (exothermic dispersion) technology syntheses of TiAl alloy and TiC/TiAl composite materials. In conjunction with this, it probes the synthetic reactive mechanisms. Results clearly show that it is possible to use--in the vicinity of the melting point of aluminum--XD techniques to prepare TiAl alloys as well as TiC/TiAl composite materials reinforced with TiC particles as well as that thermopositive reactions between Ti-Al powders promote the synthesis of TiC. TiAl alloy is composed of TiAl+Ti3Al phases, and TiC/TiAl composite materials are composed of TiC+TiAl+Ti3Al phases.

KEY WORDS Synthetic metals Composite materials Constitution

Chinese Library Classification No. V257 TB331



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TiAl metallic intermediate compounds are limited in their applications by the fact that they are brittle at room temperature and their high temperature strength is relatively low. Through synthesis as well as thermal processing control of their microstructures, there have already been effective improvements in the normal temperature plasticity of TiAl alloys [1,2]. Moreover, the introduction into alloys of strengthening granules (TiC, SiC, TiB2, and so on) is an effective method of improving the high temperature properties [3]. However, if one opts for the use of methods associated with external additions, there will often be influences on strengthening results due to phase boundary cohesion problems or uneven dispersion of strengthening granules. In the 1980's, the U.S. Martin Marietta Co. opted for the use of XD (exothermic dispersion) techniques to prepare TiB2 granule strengthened Al radical and TiAl radical composite materials. The basic principle is to take two types of powders associated with the production of strengthning phases and mix them with the basic powder. At a given temperature, between the two powders forming the strengthening phase, thermopositive reactions are produced thereby forming diffused strengthening phase on substrates. The research in question attempts to make use of the amounts of heat released by Ti powder and Al powder reactions at relatively low temperatures in order to promote TiC granule formation, thereby realizing the preparation of TiC/TiAl composite materials at relatively low temperatures.

1 MATERIALS AND EXPERIMENTAL METHODS

/1446

Take pure metallic Ti, Al, Ni, and C powders and burden in accordance with Table 1.

表 1 元素 Al、Ni、C、Ti 在各合金中含量(at%)

(1) 合 金	Al	Ni	C	Ti
TiAl	50			(2) 余量
TiAl-10%TiC	43	4	5	余量
TiAl-20%TiC	38	4	10	余量
TiAl-30%TiC	33	4	15	余量

Table 1 Amounts of Elements Al, Ni, C, and Ti Contained in Various Alloys (at%)

Key: (1) Alloy (2) Remainder

After mixing powders, drying in a vaccuum is carried out. Following that, pressure blanks are formed with compactness of 70% ± 2%. Synthetic reactions are completed within exothermic dispersion furnaces. Tests are carried out under vaccuum. X ray diffraction analysis of reaction products is carried out on RU-200 rotating anodes. Option is made for the use of CuKa radiation. Tube voltage is 20kV.

2 EXPERIMENTAL RESULTS AND ANALYSIS

2.1 XD Synthesis of TiAl and TiC/TiAl

Fig 1 shows initiation times for pressure blank synthesis reactions under different preheating temperatures. When temperatures are ≤ 600°C, mixed powder pressure blanks do not produce reactions. With temperatures ≥ 660°C, pressure blanks produce reactions. Strong light is given off during reactions.

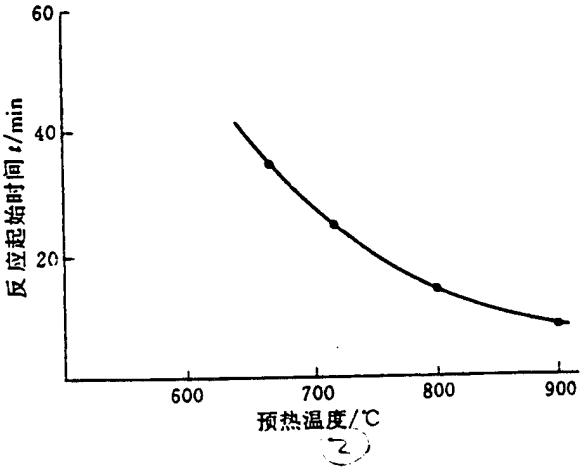

Fig.1 Ti-Al Powder Reaction Start Times with Different Preheating Temperatures

Key: (1) Reaction Start Time (2) Preheating Temperature

Products present a solid state. In conjunction with this, they give rise to uniform expansion. Densities ■ are approximately 50%±2%. Fig.2 shows the look of powder pressure blanks before and after reactions. It can clearly be seen that compactnesses drop after reactions. The reasons are (1) that the molar volume of products is smaller than the molar volume associated with reactants, and, (2) there are still small hole channels left over from when gases in powder pressure blanks suffered thermal expansion and escaped out.

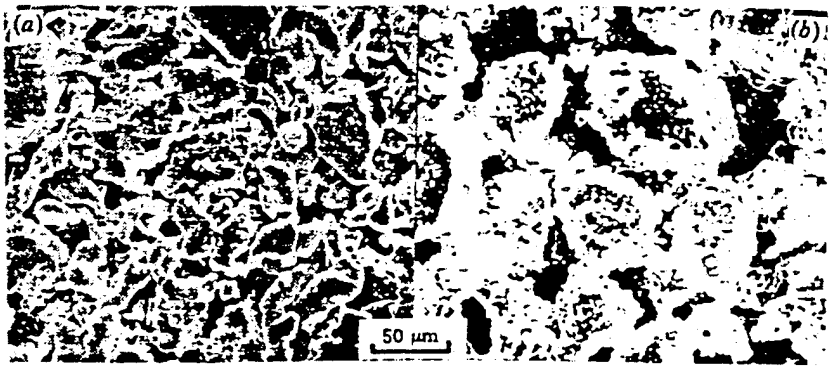

图 2 Ti-Al 压坯反应形貌

(*a*) 600℃ / 2h; (*b*) 660℃ / 34min

Fig.2 Ti-Al Pressure Blank Reaction Appearance

Selection is made of 800°C to carry out XD synthesis of TiC/TiAl series powder pressure blanks. Under this preheating temperature, pressure blanks give rise to reactions, and, in conjunction with this, they take a liquid form. In this system, besides thermopositive reactions between Ti powder and Al powder, there are also other thermopositive reactions produced.

2.2 X Ray Diffraction Analysis of Reaction Products

X ray diffraction results associated with TiAl series XD synthesis products at different preheating temperatures To (Fig.3) clearly show that powder pressure stock--after going through 600°C for 2h--are still mechanical mixtures of Ti and Al. No other phases were discovered to exist. There were definitely no reactions produced. With regard to X ray diffraction analyses

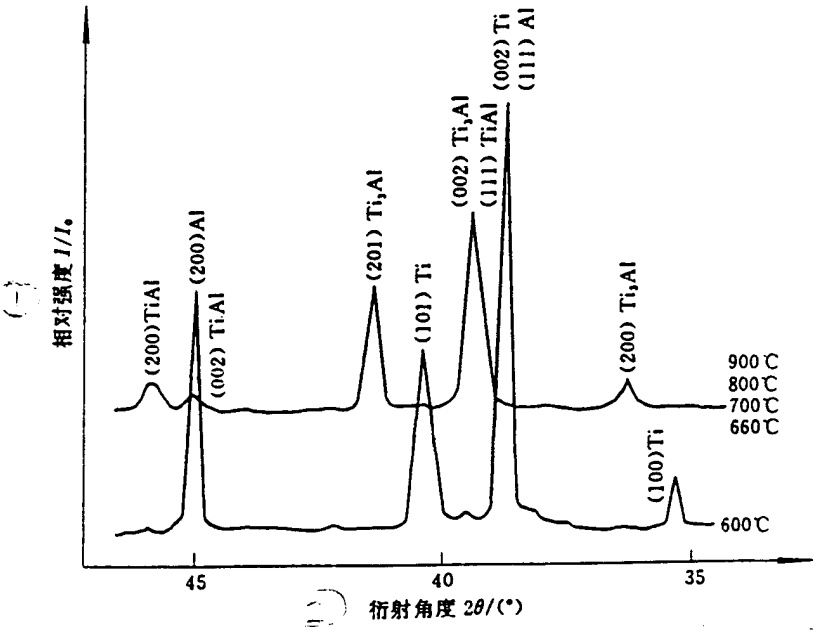

Fig.3 X Ray Diffraction Spectra Associated with Ti-Al Powder Products at Different Preheating Temperatures (1) Relative Strength (2) Diffraction Angle carried out on reaction products associated with Ti and Al pressure blanks at all preheating temperatures ≥ 660°C, among reaction products, besides the appearance of diffraction peaks associated with TiAl(■), there also exist diffraction peaks for Ti3Al(α2). However, TiAl crystal lattice parameters ao = 0.281nm and co =0.403nm as well as Ti3Al crystal lattice parameters ao = 0.573nm and co = 0.464nm

all changed with respect to TiAl and Ti3Al crystal lattice parameters given on ASTM cards.

X ray diffraction analysis associated with TiC/TiAl series XD synthetic products are shown in Fig.4. Besides diffraction peaks for TiAl and Ti3Al, diffraction peaks also exist associated with TiC among spectral lines.

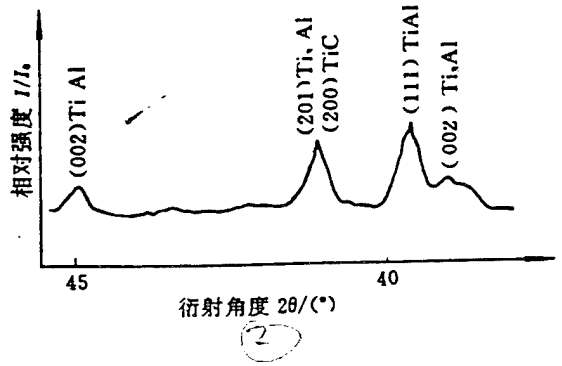

Fig.4 X Ray Diffraction Analysis Associated with TiC/TiAl Composite Materials

Key: (1) Relative Strength (2) Diffraction Angle

2.3 Microstructure Appearance of TiC/TiAl series Composite Materials

The metallic phase structure appearance of TiC/TiAl series composite materials containing different amounts of C is shown in Fig.5. The equilibrium structure for all is TiAl+Ti3Al+TiC. In accordance with calculations of all the reactions produced in association with all amounts of carbon contained in alloy series, the amounts of TiC contained in the three types of structures account for 10, 20, and 30at%. /1448

图 5　不同含 C 量的 TiC / TiAl 复合材料的金相组织

(*a*) 5at%C;　(*b*) 10at%C　(*c*) 15at%C

Fig.5 Metal Phase Structure of TiC/TiAl Composite Materials Containing Different Amounts of C

2.4 Microhardness

Fig.6 gives microhardnesses for TiC/TiAl composite materials. When amounts of TiC contained are relatively low, microhardness follows amounts of TiC contained and changes relatively quickly. However, following further increases in the amounts of TiC contained, the range of microhardness increases becomes relatively small.

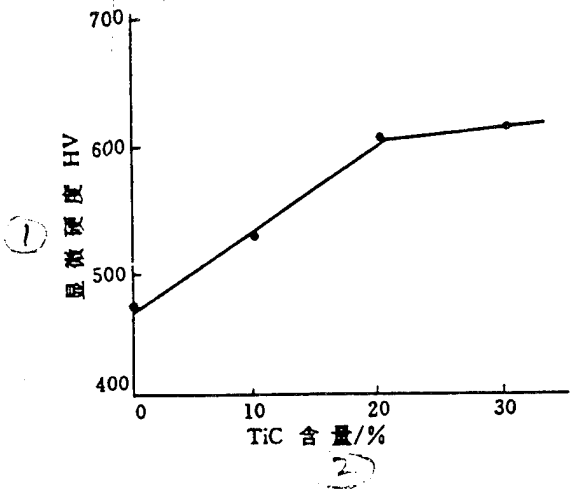

Fig.6 Influences of Different Amounts of TiC Content on TiC/TiAl Microhardness

Key: (1) Microhardness (2) Amount of TiC Contained

3 DISCUSSION

Inital XD synthesis temperatures for TiAl are roughly equivalent to the Al melting point. During synthesis of TiAl+TiB2 composite materials (initial temperatures are 630-648°C), reference [4] is roughly equivalent to the initial

temperatures when the authors made use of XD techniques to prepare TiC+NiAl. During tests, XD synthesis was carried out on Ti-50Cat% powder pressure blanks at 800°C and 900°C. In all cases, reactions were not produced. As a result, it is possible to recognize that the formation of TiC in TiC/TiAl series is caused by thermopositive reactions between Ti-Al. Before the beginning of synthetic reactions, the whole powder system is heated to the vicinity of the melting point of Al. After Al in a fused state comes in contact with Ti powder, thermopositive reactions are produced--3Ti+Al --> Ti3Al, Ti+Al --> TiAl, and so on, thereby making the temperature of the whole system abruptly go up and leading to the occurrence of reactions in the whole system. Temperatures go to the melting point of Ti or above, satisfying the conditions for the violently thermopositive reaction Ti+C -> TiC and making the reaction products of the system appear in a liquid state. The basic process is shown in Fig.7.

TiAl alloy is composed of TiAl+Ti3Al phases. TiC/TiAl composite material is composed of TiC+TiAl+Ti3Al phases. There is a strong relationship between Ti3Al phase formation, on the one hand, and Ti powder granules. Due to reaction processes being controled by atomic diffusion, there is limited gathering of abundant Ti to form Ti3Al phase. On the other hand, by contrast, there is a relationship with the relatively low activation energies associated with the reaction 3Ti+Al -> Ti3Al. Research which has already been done [5] clearly shows that small amount of Ti3Al(α1) phase existing in the basic alloy TiAl(■) is advantageous to making structures fine. In conjunction with this, it increases plasticity.

Changes in TiAl and Ti3Al phase crystal lattice parameters are related to these two phases, and, in conjunction with that, to nonideal atomic compounding ratios. Due to the atomic compounding ratios of Ti powder and Al powder being 1:1, it is possible to recongnize that, in TiAl, atomic ratios of Ti and Al can be smaller than 1. Morever, in Ti3Al, Ti and Al atomic ratios do not reach 3:1.

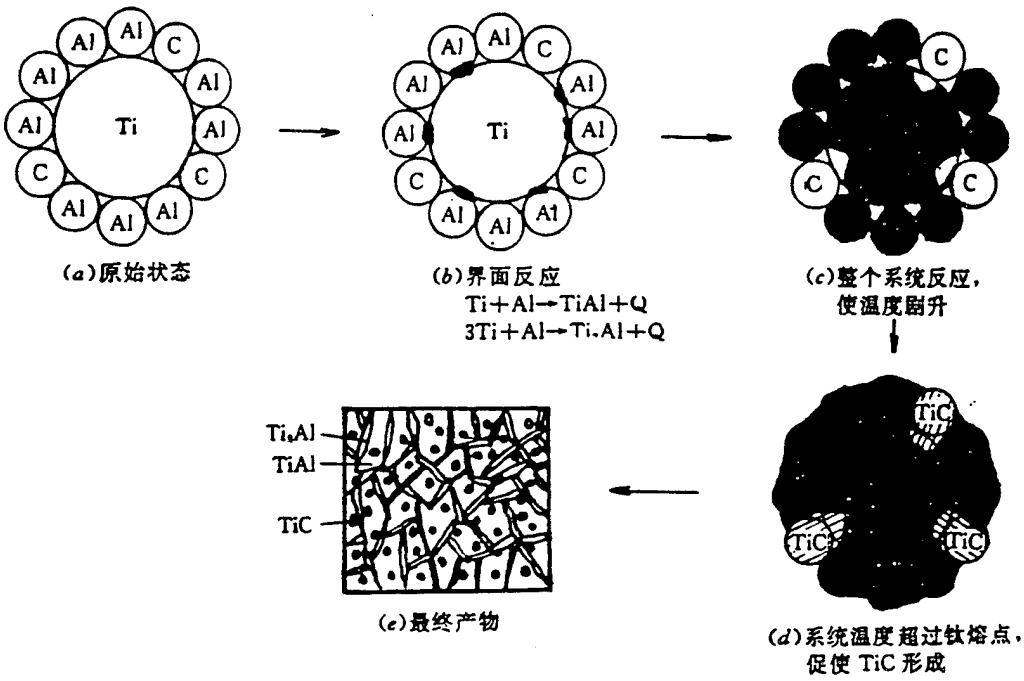

Fig.7 TiC/TiAl Synthetic Reaction Schematic (a) Original Configuration (b) Boundary Surface Reaction (c) Whole System Reaction Causes Abrupt Temperature Rise (d) System Temperatures Exceed the Melting Point of Titanium Spuring the Formation of TiC (e) Final Product

4 CONCLUSIONS

(1) Initial temperatures associated with TiAl powder synthesis reactions are roughly equivalent to the melting point of Al.

(2) Opting for the use of pure Ti, Al, and C powders--under relatively low temperatures--it is then possible to synthesize TiC granules, strengthening basic TiAl composite material. Thermopositive reactions produced between Ti-Al promote the synthesis of TiC.

(3) TiAl alloy is composed of TiAl+Ti3Al phases. TiC/TiAl composite material is composed of TiC+TiAl+Ti3Al phases.

REFERENCES

1 Kawabata T, Tamura T, Izumi O. Effect of Ti / Al ratio and Cr, Nb, and Hf additions on material factors and mechanical properties in TiAl. Metall Trans, 1993; 24A(1): 141-149

2 Zheng Y, Zhao L, Tangri K. Microstructure evolution during heat treatment of a Cr-bearing Ti_3Al+TiAl alloy. Scripta Metal et Mater, 1992; 26(2): 219-225

3 黄培云.粉末冶金原理. 北京：冶金工业出版社,1982: 407-409

4 曲选辉，黄伯云，雷长明，陈仕奇. TiAl+TiB_2复合材料制备过程及其热稳定性的研究.金属学报，1993; 29(5): B236-B241

5 郝士明，赵泉.Ti-Al金属间化合物双相合金组织的研究.见：仲增墉，叶恒强等编.金属间化合物，全国首届高温结构金属间化合物学术讨论会，北京：机械工业出版社，1992: 210-214

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